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LIFT AND DRAG TESTS OF THREE AIRFOIL MODELS WITH FOWLER FLAPS SUBMITTED BY CONSOLIDATED AIRCRAFT CORPORATION

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for

Materiel Division, Army Air Corps

LIFT AND DRAG TESTS OF THREE AIRFOIL MODELS WITH FOWLER FLAPS SUBMITTED BY CONSOLIDATED AIRCRAFT CORPORATION

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INTRODUCTION

Lift and drag tests were made in the Langley two-dimensional tunnel of three airfoil models submitted by the Consolidated Aircraft Corporation. The models represented intermediate sections on alternative wings of the XB-32 airplane and were equipped with 0.3c Fowler flaps.

The three alternative wings, sections of which were represented by the models, were as follows:

1. A Davis wing.

2. A wing obtained by adding a glove to the Davis wing with a forward extension of the leading edge. The resulting shape approximated a low-drag type section over the forward portion while retaining the shape of the Davis wing over the rear portion. Such a glove, if applied over existing structure, would increase the chord of the wing and reduce the relative thickness. The model, however, was of the same chord and thickness as the other models. This section was designated C.A.C. by the Consolidated Aircraft Corporation and is so designated throughout this report.

3. A wing with the NACA 65,2-221, $a = 1$ section at the root and the NACA 66, 2X-416, $a = 0.6$ section at the tip. This model is designated the NACA low-drag model.

The models were tested with various flap deflections up to 40°. Most of the tests were made at a value of the Reynolds number of about 6,000,000. Additional flap positions were tested on the model representing the NACA low-drag wing to improve the drag of the section in the cruising and climbing ranges of lift coefficients and to obtain improved maximum lift coefficients.

DESCRIPTION OF MODELS

The models were constructed by the Consolidated Aircraft Corporation and were of 24-inch chord and approximately 18 percent thick. The models were equipped with pressure-distribution orifices.

The models were constructed of wood and metal. The greater part of the main airfoil surface was finished with paint. The metal flaps were attached with four brackets, a separate set of brackets being provided for each flap deflection. For these tests, one flap bracket of each set was not used to allow a sufficient spanwise space free of brackets to permit drag measurements to be made. As received, the tubes from the pressure orifices in the flaps projected from the flap leading edges in such a manner as to interfere with the flow through the slot. These tubes were removed and will be replaced later as required for pressure-distribution measurements. The appearance of the models with these tubes removed and with three flap brackets in place as tested is shown in figures 1 and 2. During the first tests on the Davis model, considerable trouble was experienced by vibration of the plate forming the lip of the airfoil. Braces to stiffen this plate were accordingly installed on all models as shown in figure 3.

TEST METHODS

The models were tested in the Langley two-dimensional tunnel, which is characterized by an extremely low air-stream turbulence. The models extended from wall to wall of the rectangular test section. Lift data were obtained by means of a manometer arrangement which integrated the lift reaction of the model on the floor and ceiling of the tunnel test section. Comparison of such readings with lifts obtained from model pressure distributions has shown the method to be reliable. Drag data were obtained by the wake-survey method, using an integrating manometer.

Most of the tests were made at tunnel pressures of either 3 or 4 atmospheres. Care was taken to avoid airspeeds which might involve compressibility effects at high lift coefficients.

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The values of the section lift coefficients should be corrected by the following equations, which were not applied when the data were computed:

Davis airfoil: $c_{l(\text{corrected})} = 0.978c_l + 0.024c_{l_b}$

C.A.C. airfoil: $c_{l(\text{corrected})} = 0.993c_l + 0.013c_{l_b}$

NACA low-drag airfoil:

$$c_{l(\text{corrected})} = 0.992c_l + 0.015c_{l_b}$$

where c_{l_b} is the section lift coefficient at $\alpha = 2^\circ$ for both the Davis and the C.A.C. airfoil. For the NACA low-drag airfoil, c_{l_b} is the section lift coefficient at $\alpha = 1^\circ$.

RESULTS AND DISCUSSION

Davis Model

Lift curves for the Davis model plotted against angle of attack are presented in figure 4 for flap deflections of 0°, 5°, 10°, 20°, and 40°. Scale effect on the maximum lift coefficients for flap deflections of 0° and 40° is shown in figure 5. This model gave a maximum lift coefficient of about 1.4 at a Reynolds number of 6,000,000, flap retracted, and about 3.4 at the same Reynolds number with the flap deflected 40°.

Profile-drag coefficients for the Davis model are plotted against lift coefficient in figure 6 for flap deflections of 0°, 5°, and 10°. This model showed favorable drag characteristics with flap retracted in the range of lift coefficients useful in cruising and climb. Deflections of the flap to 5° or 10° in the positions determined by the brackets supplied did not improve the characteristics of the airfoil in this respect.

C.A.C. Model

Lift curves for the C.A.C. model plotted against angle of attack are presented in figure 7 for flap deflections of 0°, 5°, 20°, and 40°. Scale effects on the maximum lift coefficients for flap deflections of 0°, 20°, and 40° are shown in figure 8. This model produced about the same maximum lift coefficients as the Davis model for the flap-neutral condition but lower values for the flap fully deflected, the maximum lift being about 3.1.

Profile-drag coefficients for the C.A.C. model are plotted against lift coefficients in figure 9 for flap deflections of 0°, 5°, and 20°. This model was not tested with a flap deflection of 10° because of the failure of this deflection to show favorable results on the Davis model and because of the increase in drag caused by the 5° deflection. This model gave lower drag coefficients than the Davis model at lift coefficients less than about 0.65 but higher drag coefficients at lift coefficients above this value. The minimum drag coefficient was about 0.0048 at a lift coefficient of about 0.5.

Low-Drag Model

Lift coefficients for the low-drag model plotted against angle of attack are presented in figure 10 for various flap deflections. Scale effects on the maximum lift coefficients are shown in figure 11 for flap deflections of 0°, 20°, and 40°. The maximum lift coefficient for the model with flap retracted is higher than for either of the other models and about the same (3.1) as for the C.A.C. model with flap deflected 40°.

The model was also tested with the flap deflected 30° with the flap leading edge in the same position as for the 40° deflection. The maximum lift obtained was about the same as for the 40° deflection, being 3.07 against 3.10. The slot shape for either of these conditions did not appear to be very favorable, so the model was tested with the flap deflected 30° but moved back until the flap leading edge was directly under the lip. The gap in this case was 0.021c. The maximum lift obtained in this case was 3.3 (fig. 10). Only half this increase from the previous value can be attributed to increase in chord of the section. It accordingly appears that the maximum lift of the arrangement might be improved by cutting back the lip to a position directly above the flap leading edge, if it is impractical to extend the flap fully to the existing lip location. Such a condition was not tested because cutting back the lip would spoil the model for pressure-distribution measurement on any of the existing arrangements.

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The metal forming the lip of the model was necessarily relatively thick compared to the lip on the full-scale section. This lip had been tapered to a sharp edge by removing metal from the lower surface of the lip, the upper surface conforming approximately to the airfoil contour. To investigate the effect of the lip shape, the lip was bent downwards in a break in such a manner as to duplicate the condition of thinning the lip by removing metal from the top surface of the lip instead of the lower surface. For this test the flap leading edge was under the lip and the same gap (0.021c) was preserved. The results (fig. 10) showed very little effect.

It is probable that similar flap arrangements on the other models would also improve the maximum lifts obtained.

Profile-drag coefficients for the low-drag model are plotted against lift coefficients in figure 12 for flap deflections of 0°, 10°, and 20°. This model gave the lowest drag coefficients of any of the models, flaps retracted, up to a lift coefficient of about 0.7. At higher lift coefficients, without a suitable flap, the drag was less favorable than for the Davis model. Deflection of the flap to the positions determined by the brackets supplied did not extend the low-drag range to higher lift coefficients (fig. 12).

Alternate flap positions were accordingly tested to extend the low-drag range. The new flap positions are shown in figures 13, 14, and 15 and involve moving the flap in such a manner as to keep the slot closed. Deflections of 11° and 16° measured from the flap-retracted position were tested and the results shown in figures 10 and 16. The 16° deflection appeared to be the most favorable and allowed low-drag coefficients to be obtained up to a lift coefficient of about 1.2. This position was tested with the gap in the lower surface open (fig. 15) and also with it filled with modeling clay. Filling the gap did not improve the drag. The drag tests with the gap open were made with dams of modeling clay placed in the gap on each side of the measuring position to prevent dead air from moving along the gap into or away from the measuring position. Nevertheless, the drag results with the gap open cannot be considered as accurate but probably are indicative of the drags to be expected.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 29, 1941.

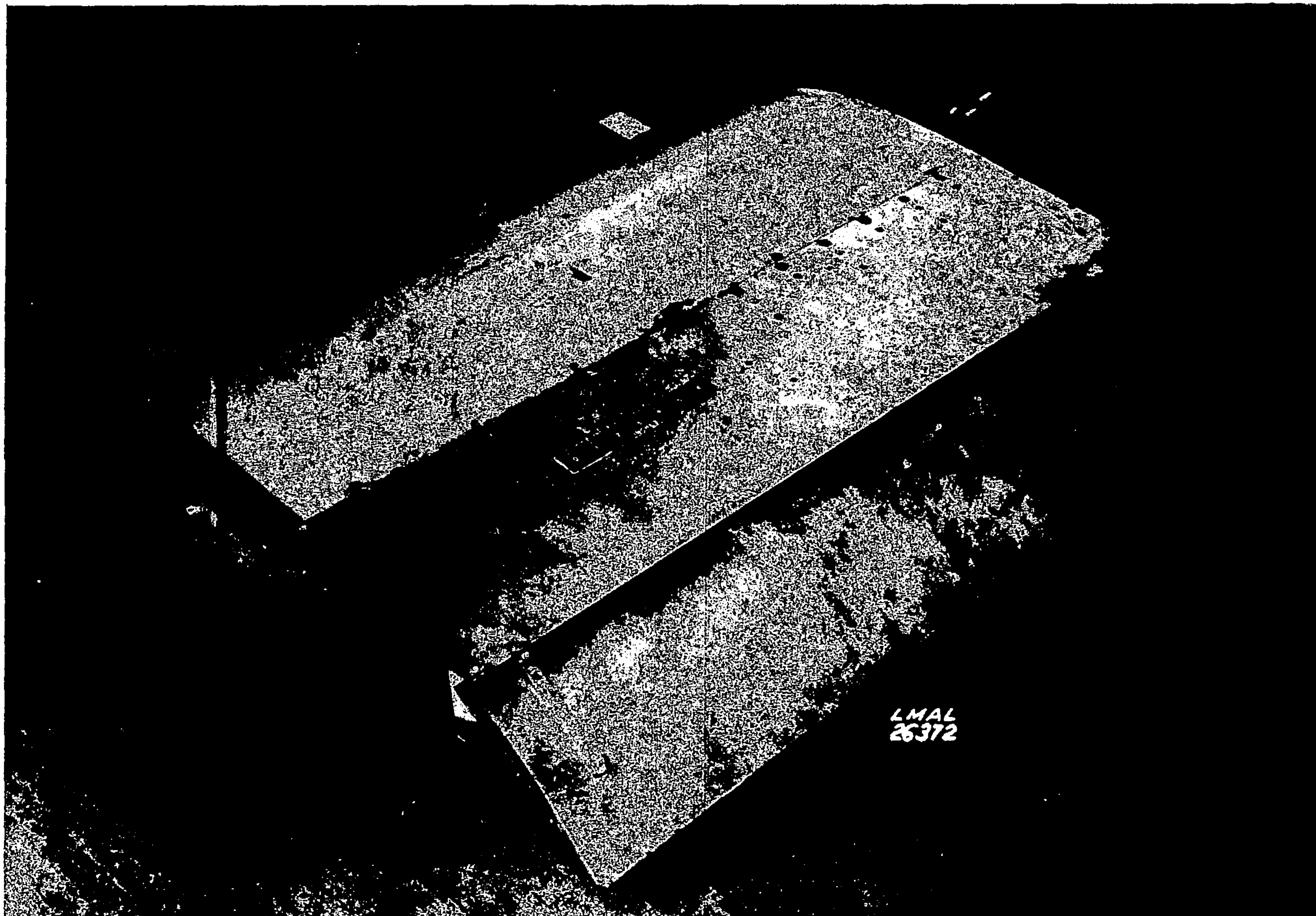

Figure 1.- Davis model with flap deflected, upper surface.

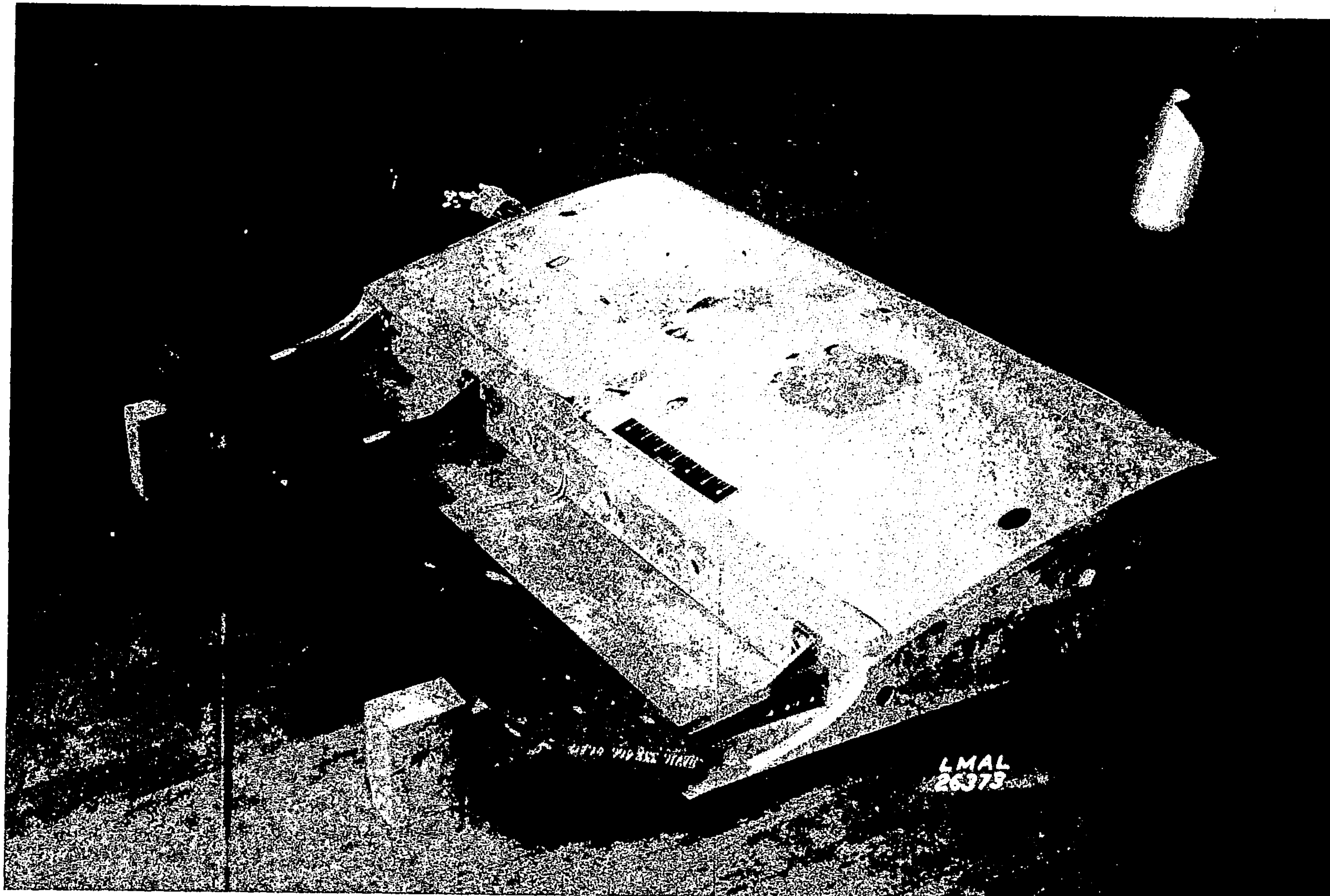

Figure 2.- Davis model with flap deflected, lower surface.

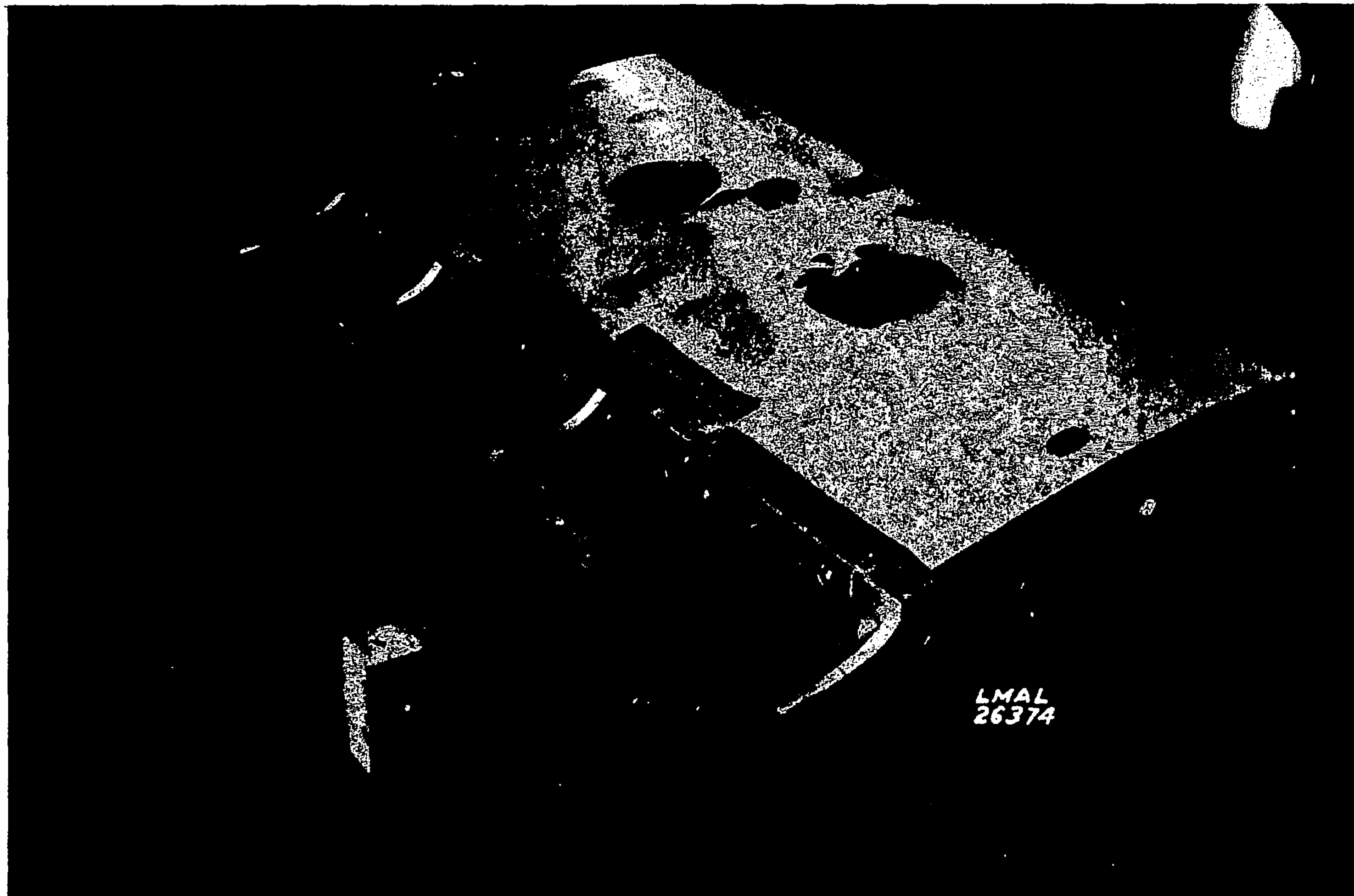

Figure 3.- Davis model showing braces installed to prevent vibration of lip.

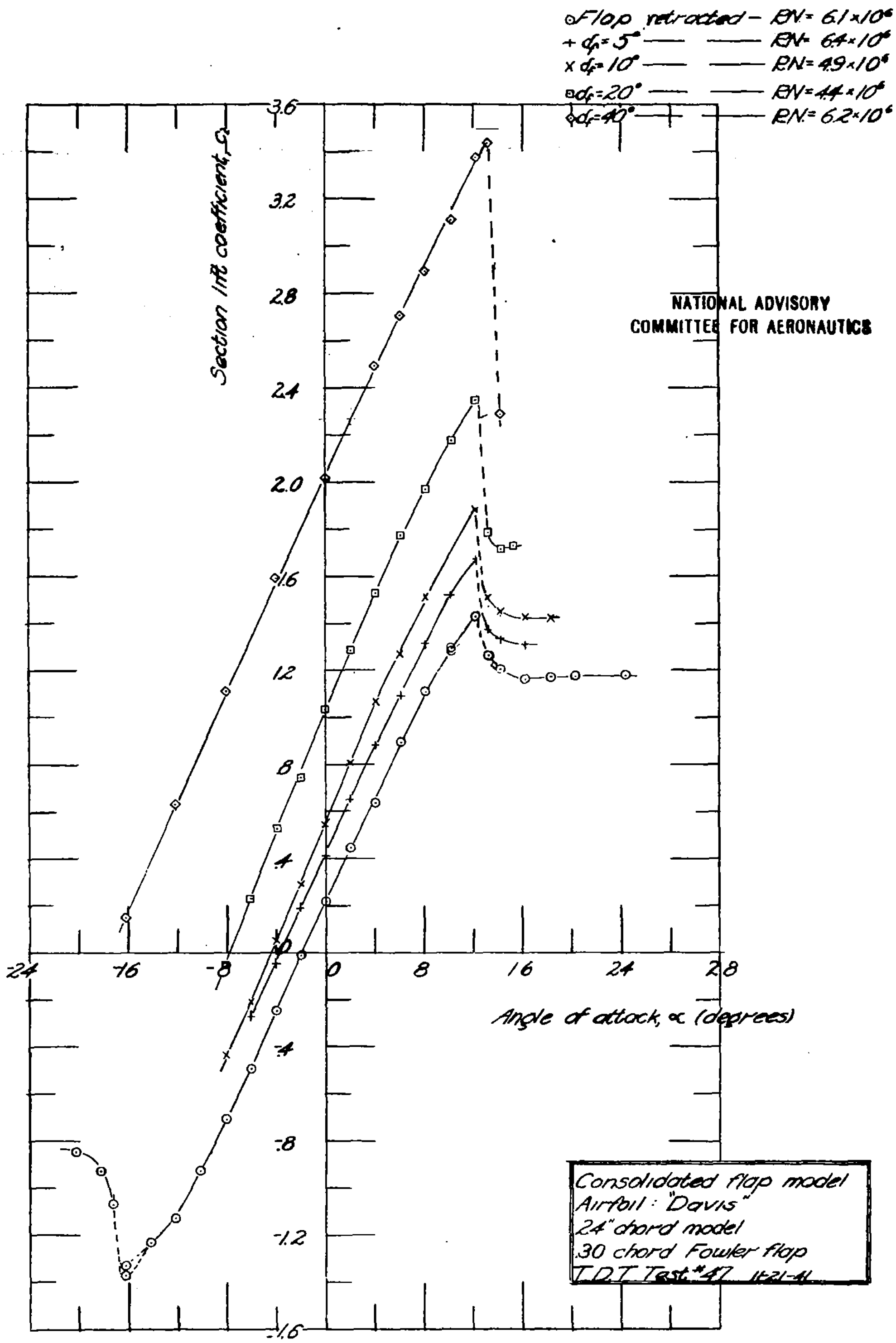

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FIG 4 Variation of section lift coefficient with angle of attack.

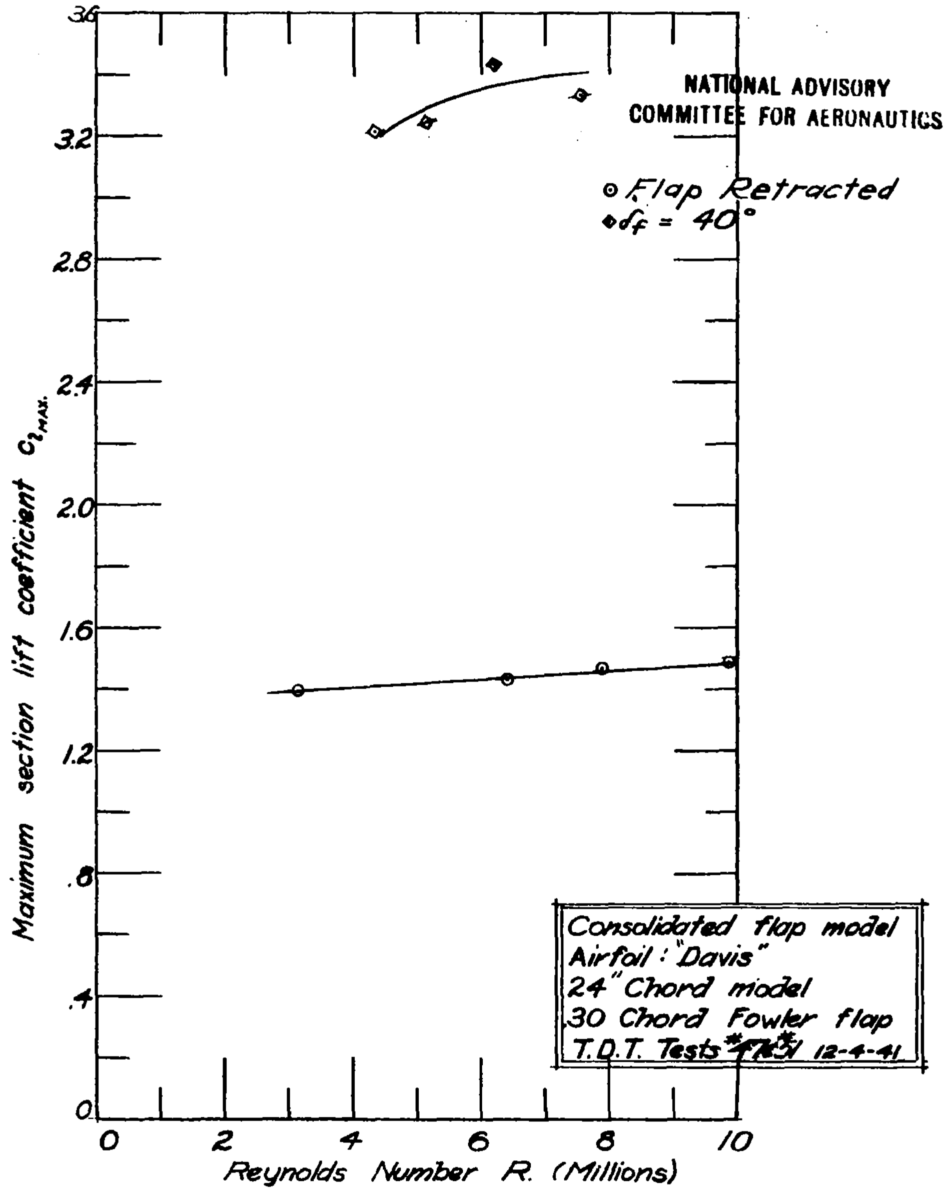

FIG 5 Variation of maximum section lift coefficient with Reynolds Number.

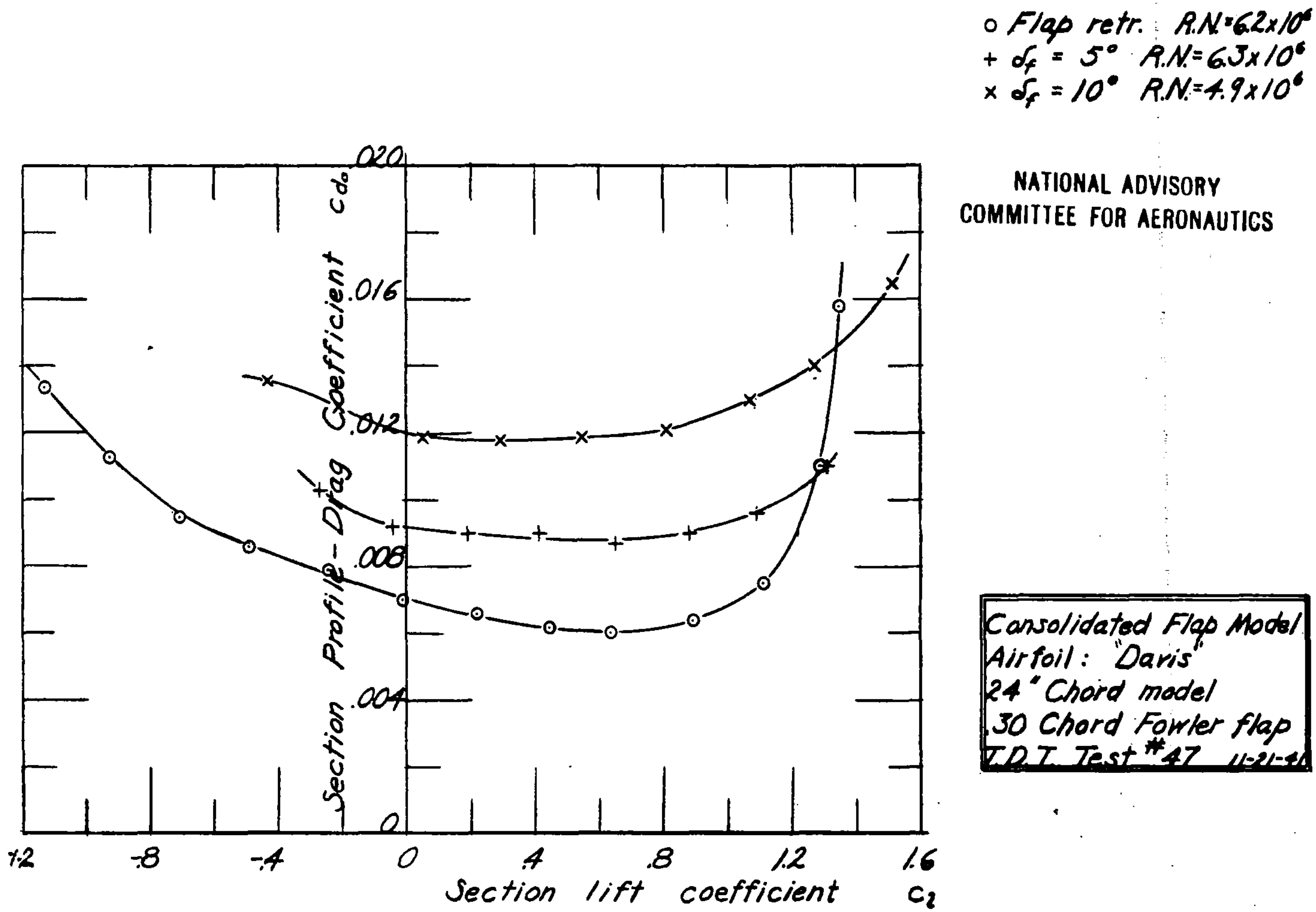

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FIG. 6 Variation of profile-drag coefficient with lift coefficient

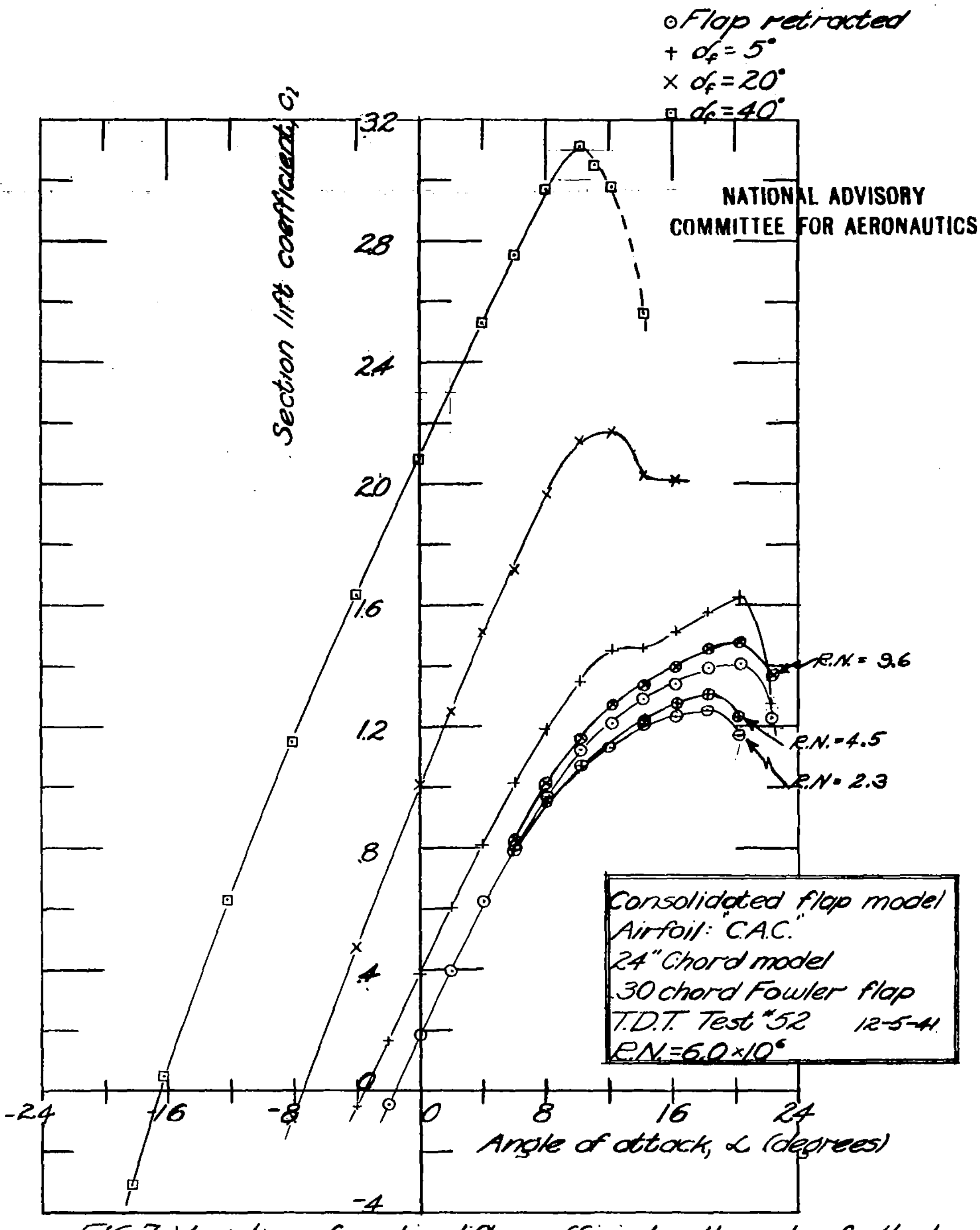

FIG 7.-Variation of section lift coefficient with angle of attack.

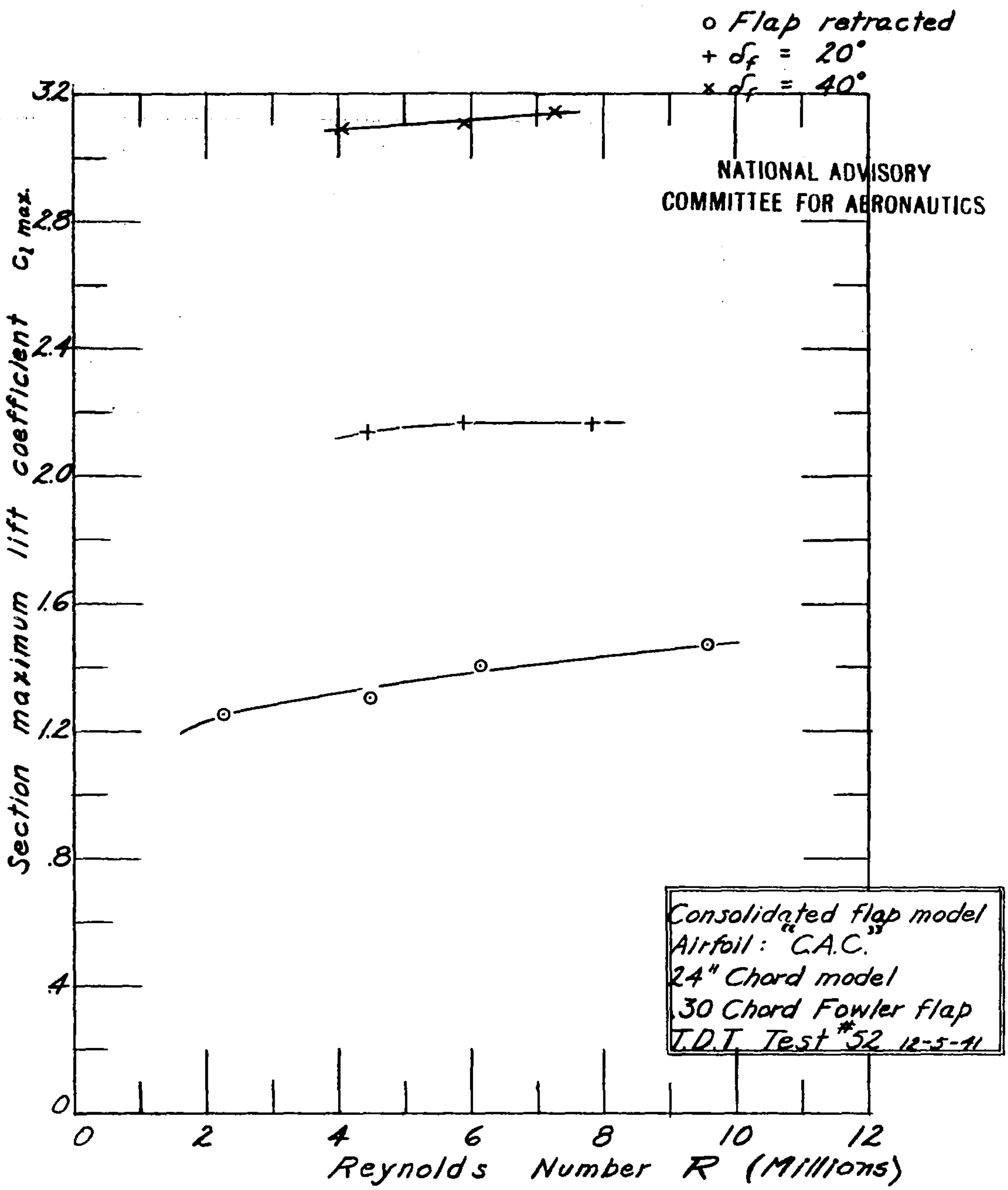

Figure 8 Variation of maximum lift with Reynolds Number

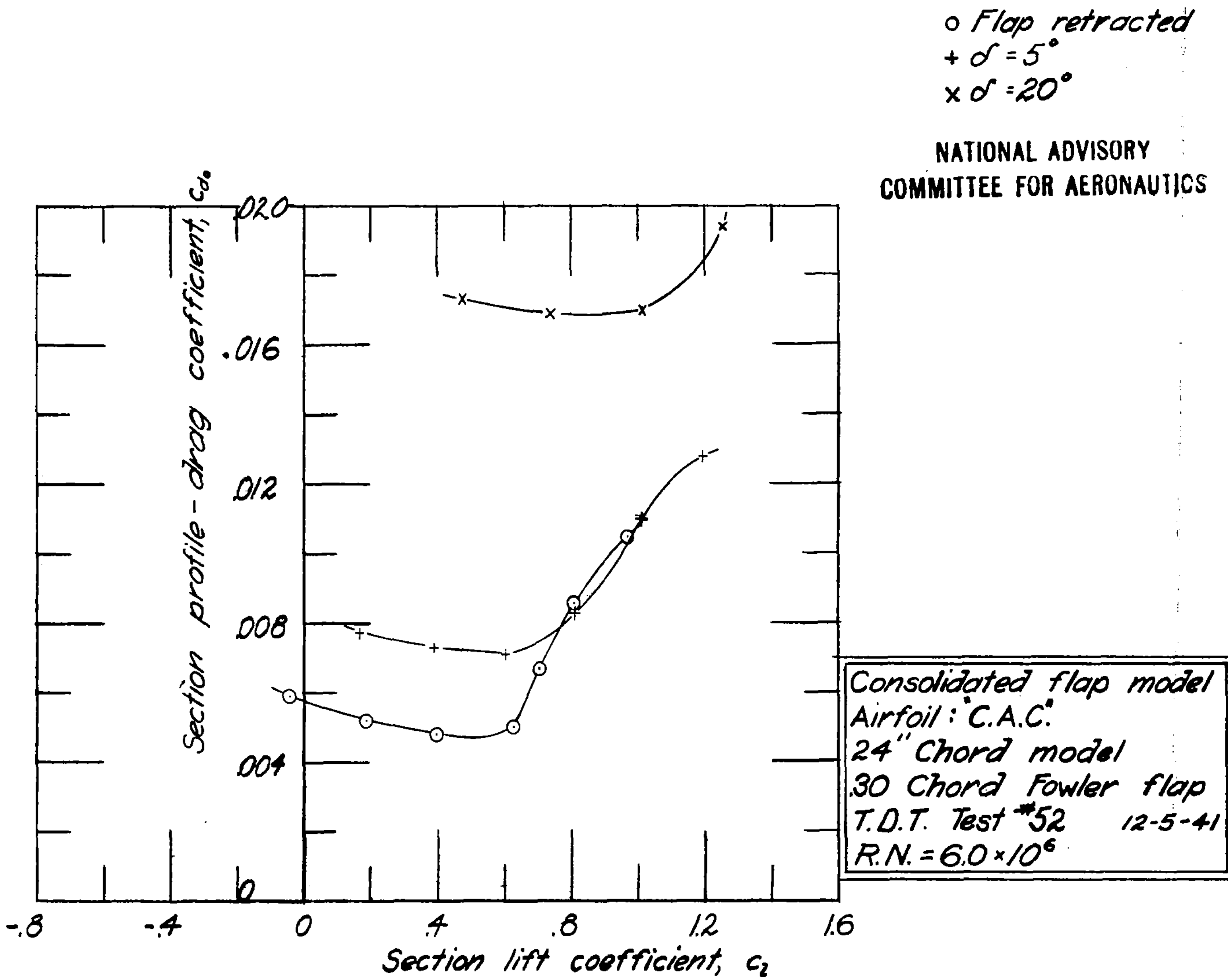

FIG 9 Variation of section profile-drag coefficient with section lift coefficient

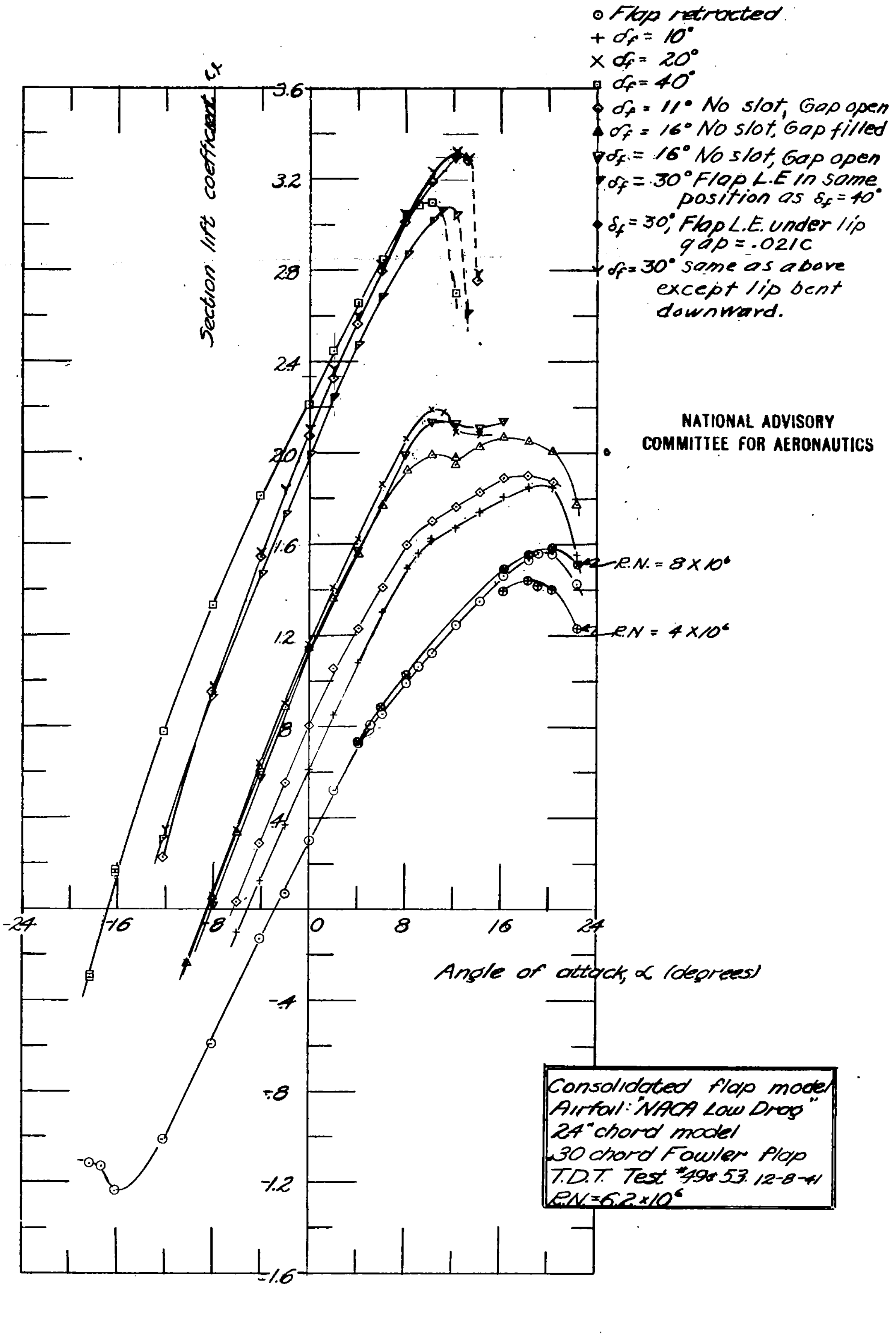

Figure 10.- Variation of section lift coefficient with angle of attack.

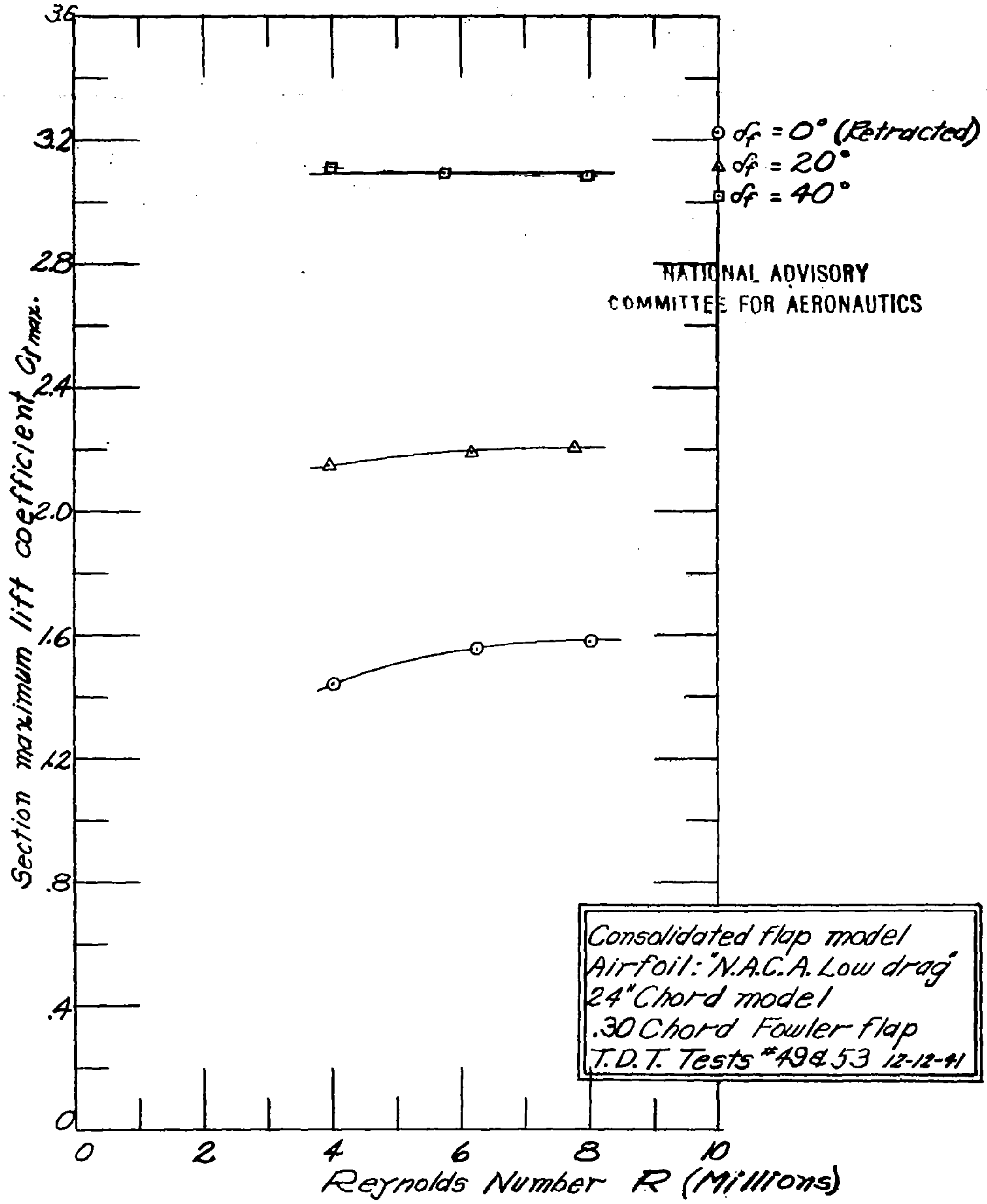

Figure 11.- Variation of maximun lift coefficient with Reynolds Number.

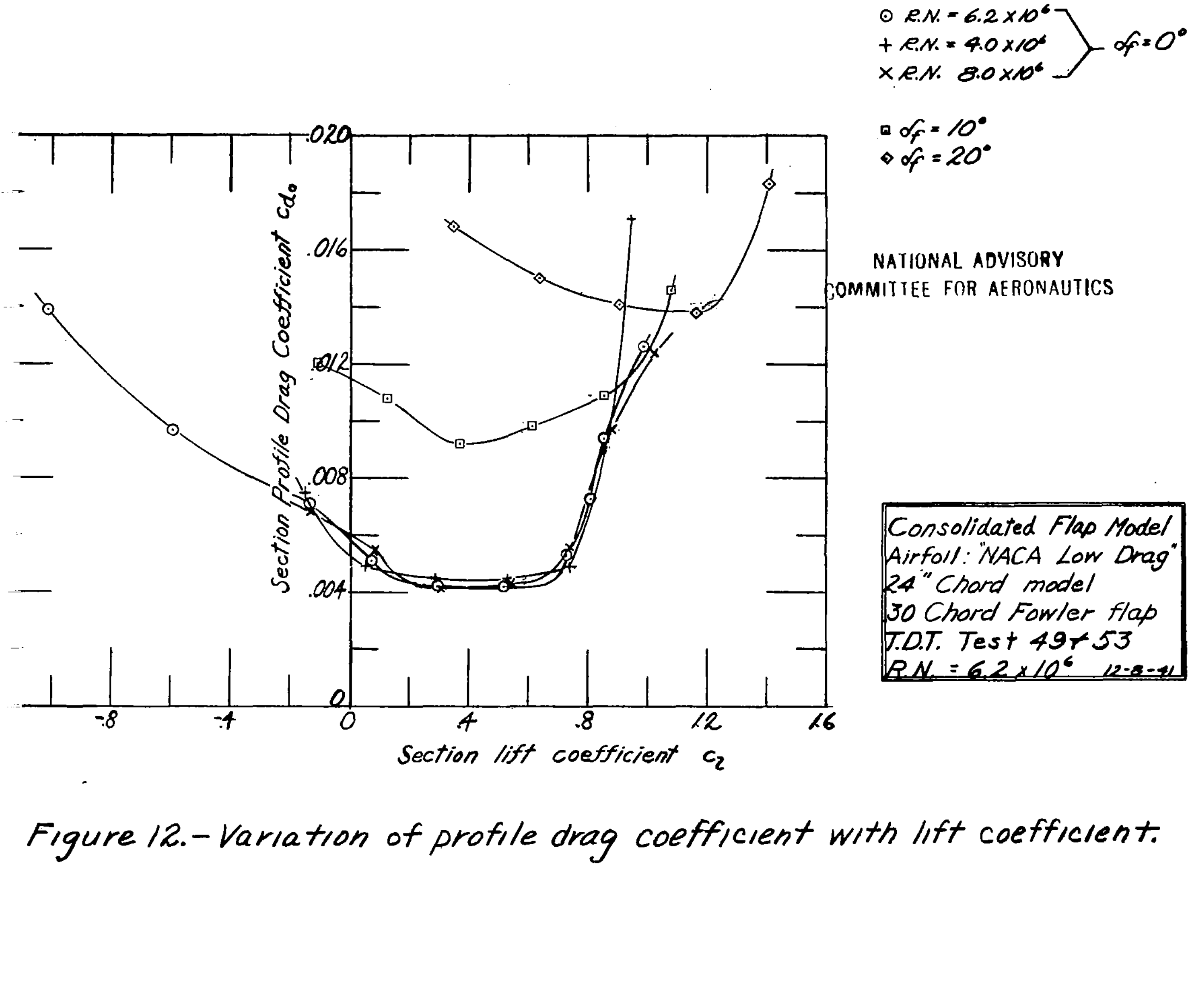

Figure 12.- Variation of profile drag coefficient with lift coefficient.

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FLAP LOCATIONS FOR DEFLECTIONS OF 11° AND 16°, NO SLOT.

24" CHORD MODEL SUBMITTED BY CONSOLIDATED AIRCRAFT CO.

LOW DRAG SECTION.

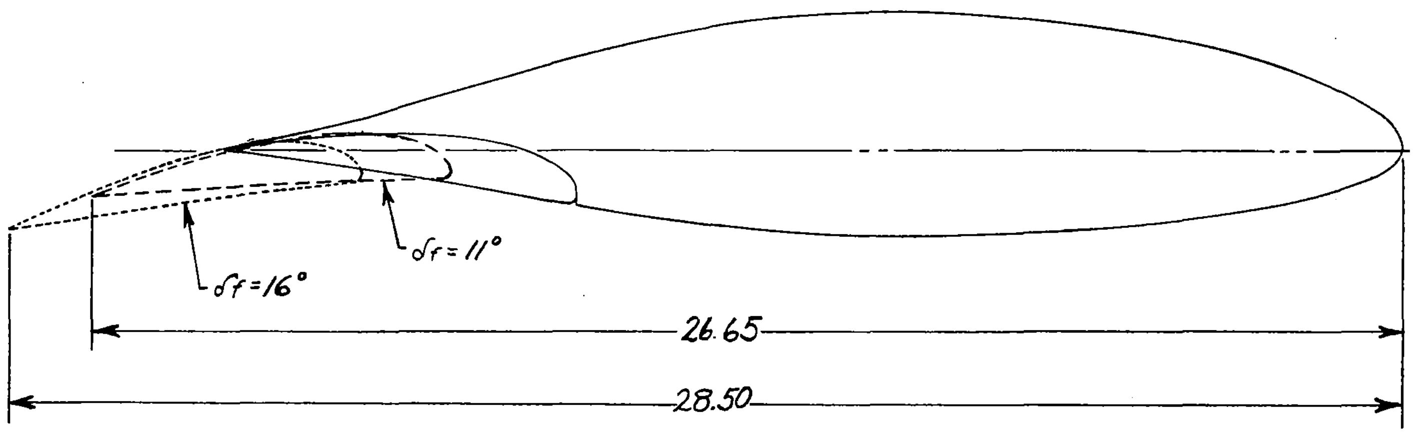

Figure 13.- Alternate flap positions.

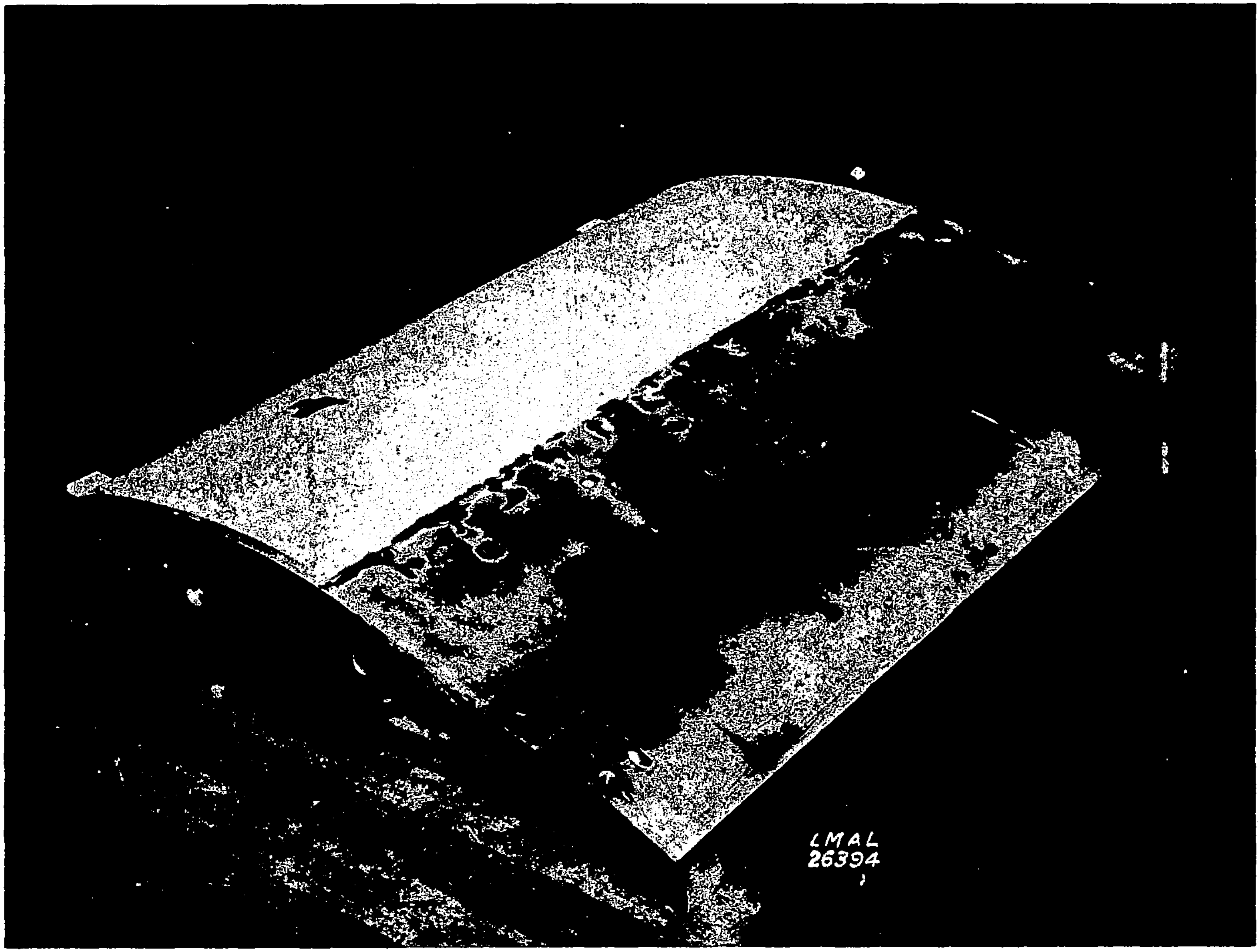

Figure 14.- Low-drag model showing alternate flap position deflected 16°, upper surface.

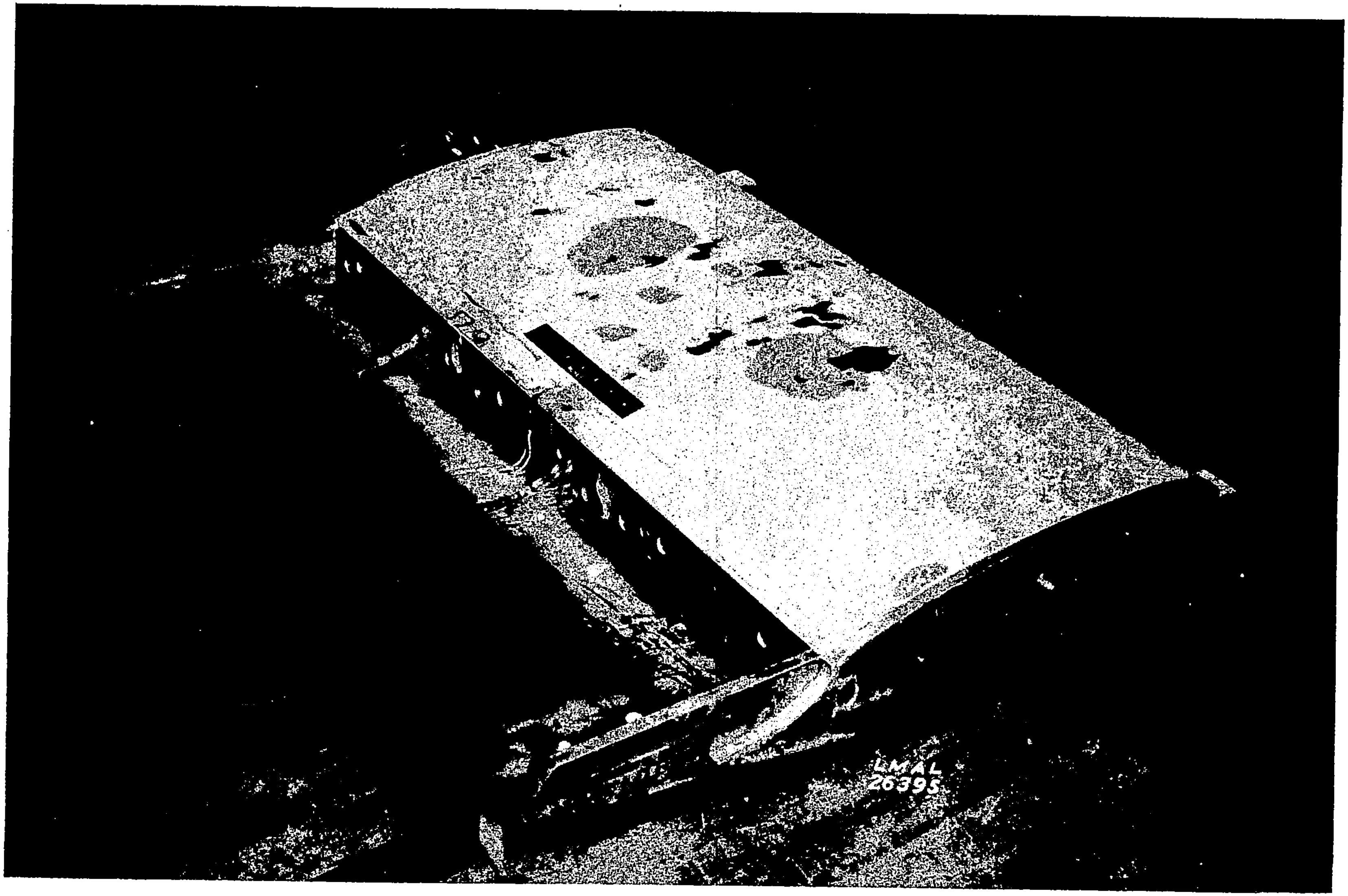

Figure 15.- Low-drag model showing alternate flap position deflected 16°, lower surface.

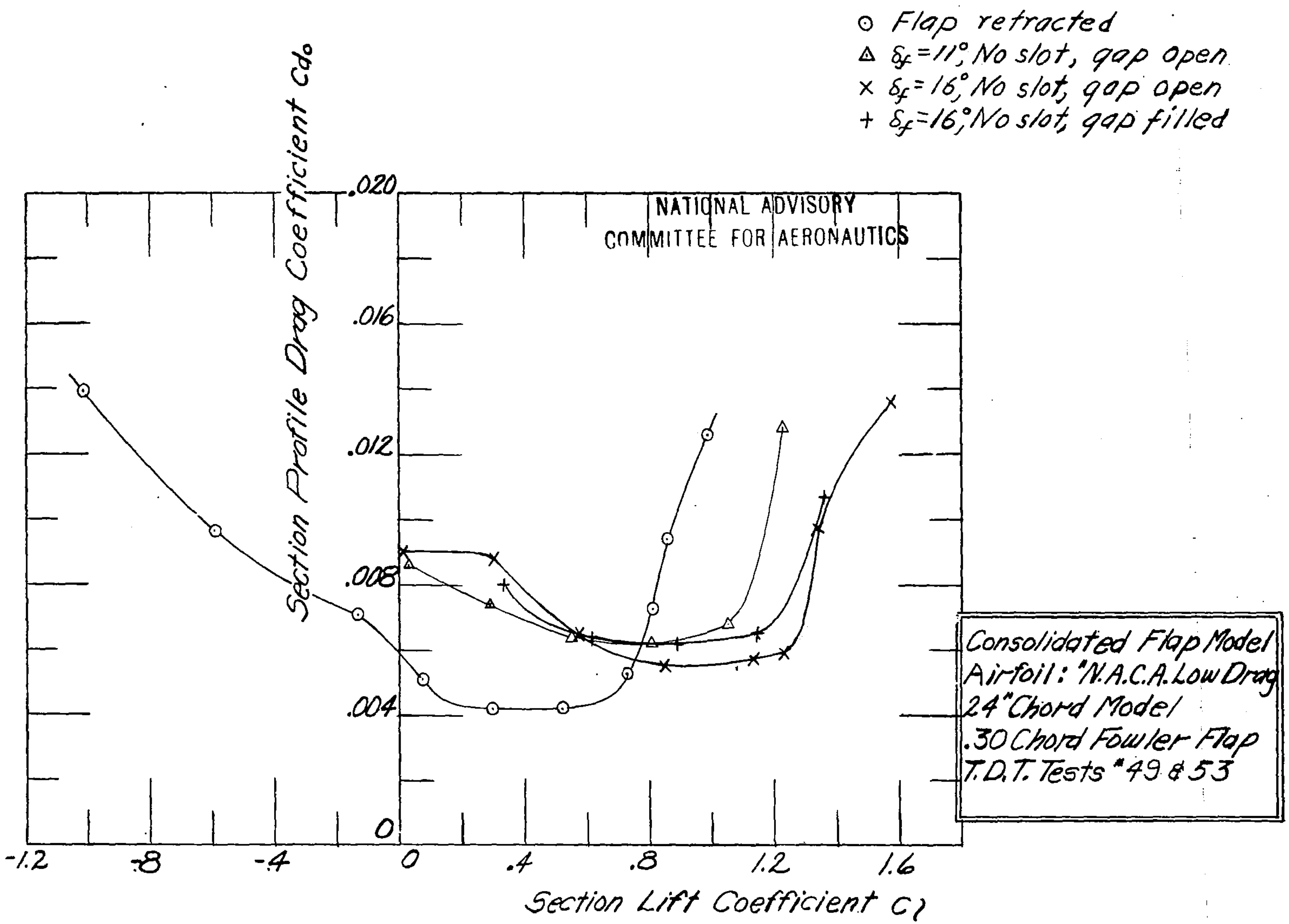

Figure 16.- Variation of profile drag coefficient with lift coefficient.